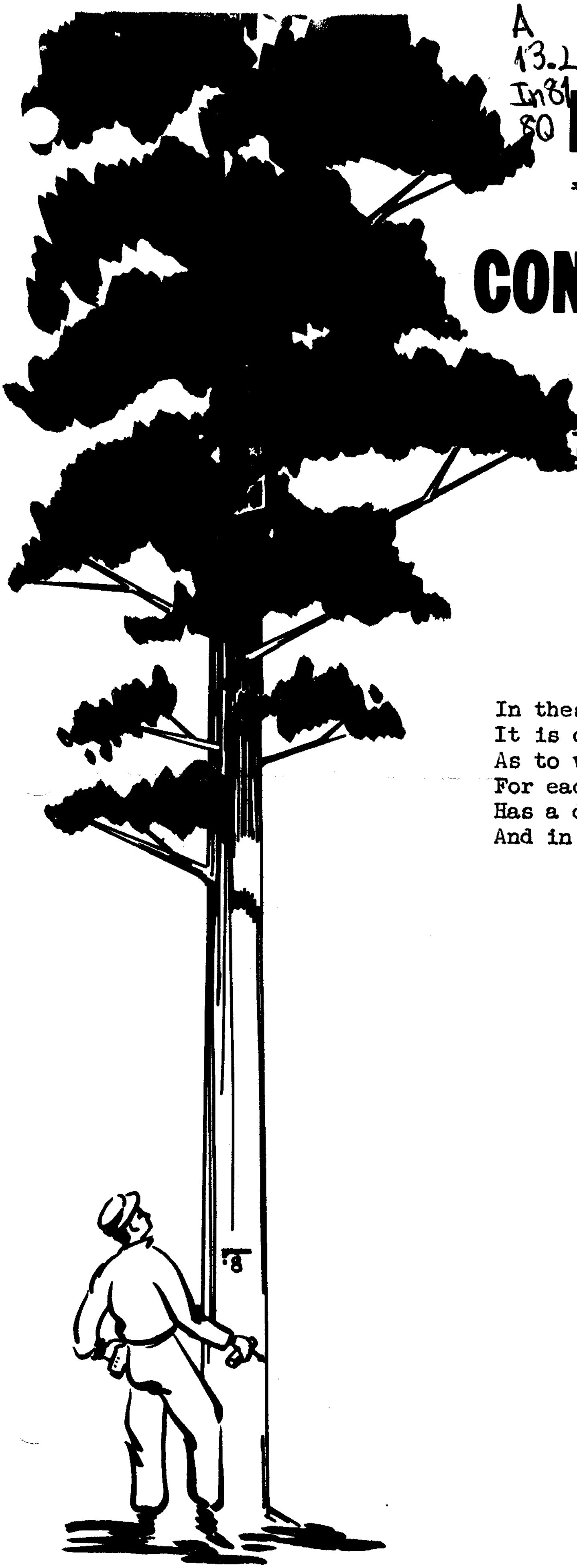

FOREST CONTROL by CONTINUOUS INVENTORY

"Today I have grown taller from walking
with the trees."
...Karle Wilson

Milwaukee 3, Wis. November, 1960 No. 80

BEETLES, BUGS OR BACILLI

In these days of indigestion
It is oftentimes a question
As to what to eat and what to leave alone;
For each microbe and bacillus
Has a different way to kill us,
And in time they always claim us for their own.

ROY ATWELL

The Forester

A FEW FACTS ON THE SPREAD OF DUTCH ELM DISEASE IN SOUTHEASTERN WISCONSIN

A BY-PRODUCT OF CFI RECORDS ON 108 FIXED RADIUS PLOTS

Permanent inventory plots in three farm woodlots near Milwaukee, Wisconsin are providing a measure of the spread of Dutch Elm disease in the vicinity of the city. The prospect is not pleasing. Both American and Slippery Elm trees are continuing to die at an increasing rate since the first recorded incidence of the disease on the study areas.

First evidence of the problem was found in 1958, on the south and east edges of two of the woodlots. By 1959 dead and dying trees were scattered all through the three tracts. A tremendous increase in the disease was evident late in the fall of 1960.

On the 21.6 acres of sample plots measured in these forest areas only one dead tree was recorded in the fall of 1958. Dead and dying trees increased to 18 within the sample plots by 1959. There was a total of 50 infected trees by 1960.

About two-thirds of the trees and 90% of the volume lost were American Elm. The lost sawlog volume was only 3 board feet per acre in 1958. This grew to a loss of 26 board feet per acre in 1959 and 252 board feet in 1960.

Nothing is now being done in these woodlots to prevent the obvious, sweeping spread of the disease in the outlying areas of the city. There seems little hope for the genus Ulmus in these three Milwaukee County woodlots.

Dutch Elm disease is induced primarily by a process of inoculation of the elm trees by beetle carriers or vectors which feed in the small twig crotches. The principal culprits are the smaller European elm bark beetle and the native elm bark beetle, which in any wooded locality precede the disease by about 8 years.

There is now no fully satisfactory solution to the beetle or disease problem. A 2% DDT emulsion spray applied before April 1 will help destroy the carriers. Felling and completely burning dead and dying elm trees before April 1 each year will destroy the beetles before they emerge from their breeding place beneath the bark.

As a preventive measure it is expedient to cut and utilize the oldest and least vigorous elms in woodlots before the trees are infected. Now is the time to call in a trained forester to mark the low vigor trees of all species, including the elms, making a moderate selective cut. Following the logging operation, all of the tops and limbs or slash of the elm trees should be burned on top of all of the elm stumps.

CAL STOTT
Forester
U. S. Forest Service, Region 9

GRAPHIC LISTING OF DEAD AND DYING ELM TREES IN SOUTHEASTERN WISCONSIN WOODLOTS INFECTED WITH THE DUTCH ELM DISEASE

1958

13" Amer Elm-58 BF

1 Tree - 58 BF

1959

32" Amer Elm-000 BF
21" Amer Elm-217 BF
15" Amer Elm-109 BF
13" Amer Elm- 47 BF
12" Amer Elm- 41 BF
12" Amer Elm- 28 BF
11" Slip Elm- 45 BF
11" Slip Elm- 36 BF
10" Amer Elm- 00 BF
10" Slip Elm- 00 BF
10" Slip Elm- 00 BF
10" Slip Elm- 00 BF
10" Amer Elm- 00 BF
10" Slip Elm- 00 BF
10" Slip Elm- 00 BF
10" Amer Elm- 00 BF
09" Amer Elm- 00 BF

18 Trees - 568 BF

1960

49" Amer Elm-000 BF
33" Amer Elm-517 BF
31" Amer Elm-634 BF
27" Amer Elm-484 BF
25" Amer Elm-597 BF
25" Amer Elm-417 BF
22" Amer Elm-369 BF
20" Amer Elm-000 BF
19" Amer Elm-131 BF
18" Slip Elm-192 BF
17" Amer Elm-158 BF
16" Slip Elm-125 BF
16" Amer Elm-153 BF
16" Amer Elm- 58 BF
15" Slip Elm-161 BF
15" Amer Elm-109 BF
15" Amer Elm-101 BF
15" Amer Elm- 80 BF
14" Amer Elm- 96 BF
14" Amer Elm- 92 BF
14" Slip Elm- 88 BF
14" Slip Elm- 68 BF
14" Amer Elm- 62 BF
13" Slip Elm-103 BF
13" Amer Elm- 90 BF
13" Amer Elm- 71 BF
13" Amer Elm- 51 BF
13" Slip Elm- 51 BF
13" Slip Elm- 38 BF
12" Slip Elm- 65 BF
12" Amer Elm- 56 BF
12" Amer Elm- 28 BF
11" Amer Elm- 46 BF
11" Slip Elm- 45 BF
11" Slip Elm- 30 BF
11" Amer Elm- 41 BF
11" Slip Elm- 35 BF
11" Slip Elm- 00 BF
11" Amer Elm- 00 BF
10" Amer Elm- 00 BF
10" Amer Elm- 00 BF
10" Amer Elm- 00 BF
10" Amer Elm- 00 BF
10" Amer Elm- 00 BF
10" Slip Elm- 00 BF
10" Slip Elm- 00 BF
10" Slip Elm- 00 BF
09" Amer Elm- 00 BF
09" Amer Elm- 00 BF
09" Amer Elm- 00 BF

50 Trees- 5,442 BF

PER ACRE LOSSES BY YEARS

Year	Trees	Board Feet
1958	.05	2.7
1959	.83	26.3
1960	2.31	251.9

Note:

No board foot volumes computed for cull sawlog trees, or trees under 11" in Breast High Diameter

FIFTH WORLD FORESTRY CONGRESS

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An Abstract Of

OUR CHANGING INVENTORY METHODS AND THE CFI SYSTEM IN NORTH AMERICA

by

Calvin B. Stott & George Semmens

Timber cruising is a never-ending task of foresters everywhere, and a responsibility which must neither be evaded nor relegated to a minor place in forestry. Essential in the early days, for short-term business reasons, timber cruising today has new procedures and purposes in harmony with the modern day sustained yield concepts. Current trends are veering away from temporary plot methods and toward Continuous Forest Inventories with permanent plots.

Continuous Forest Inventory has grown steadily over the past 25 years in the Middle West, New England, and Southern States. Its inception coincides with nation-wide forest surveys initiated by the U. S. Forest Service. Permanence in sampling began with a few growth plots established in 1937 by the Forest Service in northern Wisconsin. Today there are 50,000 permanent plots on 25 million acres of industrial and public forests in this country.

Although Continuous Forest Inventory is changing gradually over the years, it retains a core of rather fixed objectives. These include frequent repetition and direct comparison of inventories, systematic sampling, permanent, fixed radius plots, and analogous treatment of the plots and the forest. But C.F.I. is not merely an inventory tool. It is a tool to encourage better management and to gauge results, and it provides growth and mortality information not available under most other inventory systems.

C.F.I. and the opportunity it provides for periodic, tree by tree comparisons have improved timber estimates immensely in recent years. Post-inventory accuracy checks show that area and volume estimates of most cover types have a plus or minus 10 to 25 percent limit of error, with a probability of 95 percent.

To assure of an economic and continuous measurement of the never-ending changes in the forest, a systematic sampling design is used. Any change of habitat within the plot is thus a measure of the habitat change over the whole forest.

Time and cost elements of C.F.I. are moderate. Two to three single-plot stations are established in one two-man crew day. Costs, including data processing, range between 9 and 12 cents per acre.

OUR CHANGING INVENTORY METHODS
AND THE CFI SYSTEM IN NORTH AMERICA

by

Calvin B. Stott & George Semmens

The task of inventory, like the change of the seasons, is endless. It seems that all human endeavor, whether in factory, farm, or forest, is burdened with the curse of stock taking. Forest inventories are particularly difficult and costly. They disorganize management routine and add nothing to income, yet an audit of forest growing stock is essential to the management of all public and private woodland areas.

It will always be the forest manager's responsibility to make periodic accountings of his stewardship of property entrusted to his care. He has the choice of many methods, each with its own points of utility and advantage, and its standard procedures. Factors which have the greatest influence on timber inventory methods are size of area and concept of management.

Forest properties on the North American continent are extensive and only a small sample of the trees can be measured. European methods of inventory, which often record all commercial trees in the forest, cannot be used here.

The concept of forest management has a strong influence on the inventory method. A far more frequent and intensive cruise is needed for sustained-yield management than for timber liquidation. Foresters in this country are living in a period of changeover from an inventory practice designed to satisfy the needs of buying, selling, and clear cutting timber, to the kind of cruising necessary to a planned continuity of management. This new type of inventory, the principles of which originated in Europe almost 100 years ago, is commonly called <u>Continous Forest Inventory.</u>

THE DEVELOPMENT OF TIMBER CRUISING IN THE U.S.

It is interesting to trace the factors contributing to the growth and establishment of continuing inventory systems in this country over the past 75 years.

In the latter years of the nineteenth century large public and private estates were established, mainly by government grant. Custodial policies prevailed on these lands into the early part of the twentieth century and little was known of the timber volumes present. During this long period inventory work was done by land lookers and old-time timber cruisers who roamed the woods searching for minerals and blocks of pine and spruce timber. Much of the forest land in those days was held for ultimate agricultural use and little thought was given to any form of continuing inventory or management, except on certain public lands.

This attitude toward the forest changed before and during the second world war. Economic pressures between 1929 and 1950 caused management policies of most large-scale industrial forest landowners to veer strongly toward sustained yield, and more permanent inventory systems. The most important reasons for this change were: (1) the employment of many foresters in timber industries, (2) widespread acceptance of the scientific method, (3) advances in aerial photography and the fine art of photo interpretation, (4) increasing use of data-processing machinery in the solution of forest problems, (5) efficient American business methods, and their spread to the treatment and care of the forest. The industrial accountant, policy maker, administrator and forester began to encourage the establishment of the permanent sample plot during this period. They introduced the principles of frequent repetition and direct comparison into forest inventory work, and looked with strong favor upon forest management control through continuous stock taking.

There is little doubt about it; forest inventory practice, properly planned, can be used to guide and even control the rate of timber removal, it can measure growth and mortality, it can direct silvicultural practice and the order of cutting, and it can satisfy many of the accounting demands of the associated timber business. To make sure that these advantages will result, there must be a frequent measurement of the changes constantly going on in the forest. We are not cruising a forest in final equilibrium but an ecological habitat in constant motion. There can be no continuity of control over the forest without continuity of inventory.

A SHORT HISTORY OF CONTINUOUS FOREST INVENTORY

Although Continuous Forest Inventory, or CFI, is a recent method, it has already passed through several developmental stages. Beginning in 1937 and 1938, with a few hundred permanent sample plots on industrial lands in the Middle West, the techniques soon spread to the farm woodlot.

By 1948 almost 1,000 plots had been established on farm woodlands in Ohio and Wisconsin. Most of these systematically spaced plots are still being measured periodically. It was in the farm woodlot that the efficient plot taking techniques of the present day were developed. Paint numbering trees, individual tree records, vigor and quality grading, and precise measurements, all began with the tens of thousands of trees tallied on permanent plots in farm woodlots between 1940 and 1948.

During the period 1949 to 1951 several large public forests were inventoried for volume, growth, and mortality, with 1,200 permanent plots. These plots, in line with the thinking of the times, were established to secure a predecided standard of accuracy for each predetermined area of cover, size, and density class. The plots were stratified, and there was no way to measure forest changes from the plots themselves, but only by re-flying and interpreting new pictures. Since this is a method far too costly and involved to be repeated in the five-year intervals generally used with the CFI system, half of these permanent plots were dropped at the first remeasurement, and a systematic sampling plan was built around the remaining plots.

By 1952 the American Pulpwood Association became interested in more business-like inventories for industrial forest lands and had the C.F.I. system presented to its members. This cooperation between the APA and the USFS resulted in large-scale applications of CFI in pulpwood and sawlog forests east of the Mississippi Valley. The five original growth plots established in northern Wisconsin in 1937 have expanded to 50,000 plots throughout the United States. Since 1949 more than 50 owners of large industrial forests have inventoried 25 million acres with the CFI system in the U.S., and a fourth as much in Canada. All of this coverage is systematic or mechanical in sampling design.

CONTINUOUS FOREST INVENTORY OR CFI DEFINED

CFI was developed and first applied on a large scale in the Middle West. It is a method of inventory which samples the forest realistically in terms of its natural composition. It does not merely measure separate, scattered trees within the ecological habitat of the forest, but the entire habitat. All commercial trees are tallied within the plant association represented by each plot.

Widely used in the New England, Lake and Southern States, the true principles of the CFI system will help to assure the forest owner of continuity of control over most of his technical and business problems. The CFI of the past and present is quite simply defined:

> Continuous Forest Inventory, or CFI, is a precise, frequently repeated, and directly comparable measurement of all commercial trees in systematically placed sample plots. These plots have fixed radii and are permanently located in the forest. Their treatment, and the treatment of the surrounding forest must be analogous.

THE CHANGING OBJECTIVES OF THE CFI SYSTEM

The original purpose of CFI was to collect volume, growth, and mortality information indispensible to the establishment of broad management policies on large forest areas. The basic thought was to encourage better forest management and periodically gauge the effects. It was not originally planned to gather a great many interlocking details, but time and professional opinion have somewhat modified the early viewpoint. Today volume, growth, and area segregations of field data are finer, and so it has become necessary to increase the precision of work and number of samples taken. Whether the method will revert to its original purpose in the future, or become even more intensive remains to be seen. There seems now to be a slight trend toward greater intensification, with the use of CFI data in accounting records and operating schedules.

PROPORTIONATE SAMPLING ESSENTIAL

Since 1951 CFI has applied a sampling pattern which is directly proportional to nature's distribution of trees and cover types in the ecological habitat of the forest. Circular plots of one-seventh or one-fifth acre size are used. Today the single plot station is most common, but multiple plot stations have been used in the past. Plot locations are pricked through to forest maps from a master grid which establishes the plot points on the corners of squares. The plot center locations on the map are tied by distance and direction to permanent land marks easily identifiable on the aerial photographs. Deviations from the standard grid are permitted only when plots fall on ownership boundaries.

CFI is a record of tree and forest relationships. A basic function of the system is to measure volumetric and planometric changes in the forest. To facilitate this, every tree within each plot is a separate or unit record available at all times for correlation or simulation studies. Marginal or borderline cover conditions which often occupy a third to half of the total forest area are adequately sampled with the mechanical plot distribution of CFI. Since each fixed radius plot is representative of a particular area of the forest, any change in the habitat within the plot gives a measure of the habitat change within the forest.

PRECISION AND COMPARABILITY ARE IMPORTANT

CFI, with its repeated records on the same trees and plots, has pin-pointed the twin problems of errors in measurement and judgment. Hidden, in the non-comparable inventories of the past, these errors are now exposed to the full light of reason, and they are sometimes serious. To overcome the cruiser's most flagrant mistakes, CFI uses a stepped-up program of demonstration, training, supervision and measured check. Errors which escape this procedure are caught in the finer screening of the second inventory, at which time the individual tree data-processing cards used for the field tally are coded for obvious errors and corrections are noted. Mistakes are gradually eliminated in this way and there is always a firm, new foundation of accuracy for new and old inventories. Meticulous accuracy is firmly built into the CFI system. The prospect of random checks on identical trees and the long term value of every phase of the work encourage precise work habits on the part of the cruiser. This is in considerable contrast to the more ephemeral qualities of the temporary plot cruise.

Regardless of the fact that nature's universe is endlessly variable, it can be precisely measured in the dormant season. The difficulty of securing absolute answers in nature does not remove the need for precision and care in taking the records. The most strict and glorified application of the scientific method in cruising can be nullified or made ridiculous by careless work, faulty techniques, or thoughtless deviations from standards.

SAMPLING ERROR

While there is no pre-decided accuracy standard for each stratum of the forest in CFI, post-inventory accuracy checks are data processed for every stratum. It is sometimes pointed out that a systematic distribution of

fixed radius plots both over-samples and under-samples certain strata of the forest. This is true, but those who use the CFI system, particularly in the pulpwood regions where 90 percent of the trees are under 15 inches in diameter, are not concerned about this. Repeated statistical checks show that the answers for all species combined in three quarters of the area breaks are satisfactory and acceptable with the recommended sampling intensity. Total volume figures on most C.F.I. surveys have been within ± 5 - 10% on a probability of 95 percent.

TIME AND COST FACTORS

One of the most costly inventory methods with sustained-yield management, is the temporary plot or one-shot cruise, where the opportunity for periodic comparison of results is long delayed or often completely lost. In contrast, continuing inventories at five-year intervals, with direct comparisons of both sample and expanded data are reasonable industrial investments.

CFI costs in Minnesota, Michigan, and Wisconsin range between 9 and 12 cents per acre for plot establishment and 6 to 8 cents per acre for remeasurement. Initial inventories generally take about one-third more time than subsequent inventories. These costs are typical of projects in which 500 to 1,000 plots are set out at a sampling rate of one plot for 200 to 400 acres of forest land. Data processing costs on individual tree record cards are included in these estimates.

In the Lake States, with systematic sampling, sound plot techniques and careful work, a two-man crew will complete 2 to 3 permanent plots in the average working day. Half to three-fourths of the time is spent getting to and from the plots and the balance is needed to measure and record the trees within the plot.

SUMMARY AND CONCLUSIONS

CFI is one of the first and most important steps providing the forest land manager with facts essential to the stability and continuity of his forest. An inventory made by foresters directly interested in the business of timber production, CFI gives a periodic trial balance of the condition of the trees as individuals, and of the forest as a whole.

CFI is used by timber industries in their regular accounting procedures, for determination of timber depletion rates, and other tax problems, establishment of forest values, and periodic decisions on production goals, and management accomplishments. Business, and technical controls are expedited by the records from the permanent plots. The industrial accountant, business manager, and forester are today working together to control and improve the forest, using growth, mortality, and volume information secured from the permanent plots of the CFI system. It is the view of most of the industrial forestry agencies using the system that the many advantages of CFI far outweigh the few disadvantages and that the costs are reasonable.

STATISTICAL PROCEDURES LEAFLET #10

HOW TO CALCULATE THE REGRESSION COEFFICIENT

Regressions are algebraic equations (formulas) in which values are assigned to independent variables to find the value of a dependent variable.

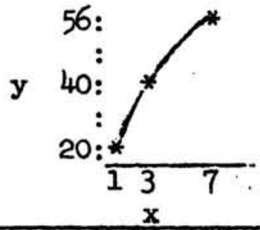
$y = Ax + K$	$y = Ax^2 + Bx + K$	$y = Ax^3 + Bx^2 + Cx + K$
(straight line)	(simple curve or parabola)	(reverse curve)

The regression coefficients are A, B and C. K is a constant -- the value of the dependent variable (y) when the value of the independent variable (x) is zero.

Regression equations are made from empirical data. The unknown factors-regression coefficients and the constant - may be calculated by the formidable method of least squares; or the data may be plotted, a rough curve drawn and an equation fitted through several selected points on the curve.

Two points determine a straight line. Four points describe a reverse curve. In the example below, the equation of a parabola is calculated from 3 selected points on its plotted curve.

EXAMPLE:



points

x	y
1	20
3	40
7	56

Form of equation:

$y = Ax^2 + Bx + K$

Step 1. Enter data in type equation:

$$56 = (7)^2A + (7)B + K$$
$$40 = (3)^2A + (3)B + K$$
$$20 = (1)^2A + (1)B + K$$

Step 2. Expand to remove exponents:

$$56 = 49A + 7B + K \quad (1)$$
$$40 = 9A + 3B + K \quad (2)$$
$$20 = 1A + 1B + K \quad (3)$$

UNKNOWNS ARE ELIMINATED UNTIL THE VALUE OF ONE COEFFICIENT IS DETERMINED

Step 3. Subtract to eliminate K

$$16 = 40A + 4B \quad (1)-(2)$$
$$20 = 8A + 2B \quad (2)-(3)$$

Step 4. Divide by coefficient of B 1/

$$4 = 10A + B$$
$$10 = 4A + B$$

Step 5. Subtract to eliminate B

$$-6 = 6A$$

Step 6. Calculate coefficient A

$$-1 = A \quad (A)$$

OTHER COEFFICIENTS ARE DETERMINED BY BACKWARD SUBSTITUTION

Step 7. Substitute coefficient A in A & B equation from Step 4.

$10 = 4A + B$, or
$10 = 4(-1) + B$, and
$10 = -4 + B$, so
$14 = B$ (B)

Step 8. Substitute coefficients A & B in A, B & K equation from Step 2.

$20 = 1A + 1B + K$, or
$20 = 1(-1) + 1(14) + K$, and
$20 = -1 + 14 + K$, so
$7 = K$ (K)

Step 9. The regression equation is:

$$y = -1x^2 + 14x + 7$$

Step 10. Check

$y = -1(7)^2 + 14(7) + 7$, or 56
$y = -1(3)^2 + 14(3) + 7$, or 40
$y = -1(1)^2 + 14(1) + 7$, or 20

1/ Carry 5 significant digits when necessary

WILLIAM WARREN BARTON, Forester, U. S. Forest Service, Region 7